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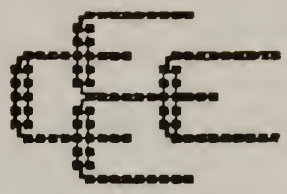
Center for Electronics and Electrical Engineering



Technical Progress Bulletin

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering

COVERING CENTER PROGRAMS, OCTOBER 1982 - DECEMBER 1982

July 1983

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

INTRODUCING THE CEEE TECHNICAL PROGRESS BULLETIN

This issue marks the introduction of a quarterly abstract journal covering the work of the National Bureau of Standards Center for Electronics and Electrical Engineering. It provides abstracts of papers approved for publication by NBS for the first quarter of Federal fiscal year 1983 (October through December, 1982). The abstracts are arranged by technical topic as identified in the table of contents and alphabetically by first author within each topic. Also listed are abstracts for papers published during the quarter. In the future, citations will provide identification of the issue of the Technical Progress Bulletin in which the associated abstract appeared. These citations will also be arranged alphabetically by first author. In addition to abstracts, information is provided, if applicable, on conference and workshop proceedings; special-format publications, such as magnetic data tapes and videotapes; new measurement services, including calibration services and standard reference materials; and a six-month calendar of Center events.

Center for Electronics and Electrical Engineering Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U. S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Materials and Processes and Semiconductor Devices and Circuits Divisions in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Names and telephone numbers of key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information.

Previous special issues: Two special issues of the Technical Progress Bulletin have been published with abstracts for the Signals and Systems Program only, NBSIR 83-2719-1, covering October 1981 through March 1982 and NBSIR 83-2719-2, covering April 1982 through September 1982. NBSIR 82-2636, a special issue of the Semiconductor Technology Program Progress Briefs published in January 1983, listed abstracts of publications from that Program for Federal fiscal year 1982 (October 1981 through September 1982, fifty-third through fifty-seventh quarters of the Program). The new CEEE Technical Progress Bulletin replaces the Progress Briefs series [single copies of 82-2636 are available from the Center, see back cover for address].

Publication lists: Guides to earlier as well as recent work are the publications lists covering the work of each division. These are revised and reissued on an approximately annual basis and are available from the originating division [the publications from the Semiconductor Technology Program are covered in a single list, available from either division].

Center sponsors: The Center Programs are sponsored by the National Bureau of Standards and a number of other organizations, in both the Federal and private sectors; these are identified on page 22.

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SEMICONDUCTOR TECHNOLOGY PROGRAM

Silicon Materials

Released for Publication

Baghdadi, A., **Multiple Reflection Corrections in Fourier Transform Spectroscopy of Back Surface Damaged Wafers,** submitted to Electrochemical Society Extended Abstracts.

In order to account properly for multiple passes of the infrared beam in back-surface damaged wafers in infrared spectrometers, the effective reflectivity of the back surface must be measured. Two methods for accomplishing this are evaluated in a comparative study. The first method is based upon an analysis of the spectrum and the second method is based upon an analysis of the interferogram. [(301) 921-3625]

Forman, R. A., Bell, M. I., Baghdadi, A., and Mayo, S., **The Effects of Striations on the Compositional Analysis of Silicon Crystals,** submitted to Electrochemical Society Extended Abstracts.

Periodic variations of composition along the growth direction in semiconductor crystals commonly arise from fluctuations in the local growth rate. These striations of impurity content can lead to systematic errors in compositional analysis by optical transmission or surface analysis techniques. A model appropriate for the analysis of such measurements is presented and estimates of probable errors are given. The model is applied to earlier published measurements on the carbon and oxygen content of silicon. The implications of these results for studies of intrinsic gettering are discussed. [(301) 921-3625]

Phillips, W.E., Thurber, W.R., and Lowney, J.R., **Improved Analysis Procedures for Deep-Level Measurements by Transient Capacitance,** submitted to Electrochemical Society Extended Abstracts.

The procedures reported here provide a way to analyze data from nonexponential transient capacitance measurements made under conditions such that (a) the traps are charged in only a part of the depletion layer or (b) the trap density is not small compared with the net shallow dopant density. This analysis requires C^{-2}-vs.-V data to be linear over the voltage range used, which may be a small range at low temperatures because of the compensation effect of traps. Computer simulations of C^{-2}-vs.-V plots are given for various ratios of trap and dopant densities at several temperatures and show ranges which are sufficiently linear, but which have a trap-density-dependent slope. These effects are illustrated by experimental C^{-2}-vs.-V, isothermal transient capacitance (ITCAP), and DLTS measurements for a wide range of densities of platinum in p^+n and n^+p silicon diodes. [(301) 921-3625]

Recently Published

Albers, J., **Spreading Resistance Probe-Spacing Experiment Simulations: Effects of Probe-Current Density and Layer Thickness,** J. Electrochemical Society 129, pp. 2788-2795 (December 1982).

Model spreading resistance data were calculated using three forms of the probe-current density: the original Schumann and Gardner version, the Choo uniform current density, and the ring delta function current density in order to determine whether probe-spacing experiment simulations are sensitive to the specific form of the probe-current density. Further, since the probes of the spreading resistance and of the four-probe sheet resistance apparatus view the material as a continuum, the dependence of the results of the probe-spacing simulation on the number of layers used in the calculation was also investigated. From the analysis, it is possible to conclude, aside from the

Silicon Materials, cont'd.

differences in the interpreted radii, that the results of the probe-spacing simulations in the surface region are not particularly sensitive to the choice of either the current density or the number of layers used in the simulation (provided, of course, that the number of layers is of reasonable size to be representative of the continuous nature of the underlying resistivity). The failure of the probe-spacing experiment simulation to obtain the correct surface sheet resistance for the case of a lightly to moderately doped layer over a substrate of the same conductivity type is not changed by either the probe-current density or the discrete layer nature of the calculations used to generate the data. The variable which has the strongest influence on the outcome of the probe-spacing experiment is the substrate resistivity. Hence, for junction-isolated layers and for heavily doped layers over substrates of the same conductivity type, probe-spacing experiments will yield the correct sheet resistance in the surface region. [(301) 921-3621]

Thurber, W. R., Forman, R. A., and Phillips, W. E., **A Novel Method to Detect Nonexponential Transients in DLTS**, J. Appl. Phys. 53, pp. 7397-7400 (November 1982).

In conventional DLTS measurements, the analysis of the results is based upon the assumption of an exponential current or capacitance transient. We present experimental and computational results on a novel experimental method for determining when the assumption of exponentiality is not satisfied by the sample under study. The measurement may be performed without any changes in the conventional double-boxcar DLTS system. [(301) 921-3625]

Insulators and Interfaces

Recently Published

Chandler-Horowitz, D., **Ellipsometric Accuracy and the Principal Angle of Incidence**, Proc. Soc. Photo-Optical Instrumentation Engineers 342, Integrated Circuit Metrology, pp. 121-130 (October 1982).

The effects of improving the accuracy of the angle of incidence on the ellipsometric determination of thickness and refractive index of oxide and nitride films on a silicon substrate are analyzed. It is found that the accuracy of a determination of a film's parameters, thickness and refractive index, depends as much or more on the accuracy of the angle of incidence measurement as on the accuracy of the measurement of the ellipsometric angles Δ and ψ. If measurements of Δ and ψ are made close to the principal angle of incidence, the accuracy of the determined film parameters can be improved by measuring the incident angle to an accuracy better than Δ and ψ. This is especially true for thin films of oxide less than a few tens of nanometers. Because of the higher refractive index of silicon nitride relative to silicon dioxide, a nitride film's thickness can be determined more accurately than an oxide film's thickness. Therefore, silicon nitride may make a good candidate film for a standard thickness sample. [(301) 921-3625]

Dimensional Metrology

Recently Published

Jerke, J. M., and Wendell, C. E., **Use of the National Bureau of Standards (NBS) Antireflective (AR)-Chromium Optical Linewidth Standard for Measurements on Other Types of Chromium Photomasks**, Proc. Soc. Photo-Optical Instrumentation Engineers 342, Integrated Circuit Metrology, pp. 15-26 (October 1982).

Both antireflective (AR)-chromium and bright-chromium photomasks are currently used in the production of integrated

Dimensional Metrology, cont'd.

circuits. Differences in the optical transmittance and reflectance of these photomasks can significantly change the line-image threshold required for accurate edge detection in optical microscope linewidth measurements. The suitability of using a calibration curve based on an AR-chromium optical linewidth-measurement standard (SRM 474) from the National Bureau of Standards (NBS) to correct linewidth measurements on other types of photomasks is discussed. Linewidths on each of three chromium photomasks of different chromium thicknesses were measured on four different types of optical microscope linewidth measurement systems. These measurements were corrected using an SRM 474 and compared with measurements made on the NBS optical linewidth calibration system. For the two bright-chromium specimens with low transmittance, the residual differences between the corrected values and the NBS values as measured on the NBS calibration system are generally less than ±0.05 μm for three of the measurement systems. For the see-through AR-chromium photomask with a higher transmittance, the calibration curve does not correct all systematic errors greater than ±0.05 μm. These results support theoretical studies showing that the degree of correction for systematic linewidth errors varies with the transmittance of the chromium photomask being measured and with the measurement system. [(301) 921-3786]

Jerke, J. M., Croarkin, M. C., and Varner, R. N., **Semiconductor Measurement Technology: Interlaboratory Study on Linewidth Measurements for Antireflective Chromium Photomasks,** NBS Special Publication 400-74 (November 1982).

Optical microscopes fitted with a micrometer attachment are commonly used to measure small linewidths and other critical dimensions on integrated-circuit (IC) photomasks. In the absence of calibrated linewidth standards, users have experienced systematic measurement errors much larger than required manufacturing tolerances. As IC linewidths approach 1 μm with a 10 percent tolerance, the need for calibration standards and improved measurement procedures becomes even more important.

This report discusses the results of an interlaboratory study to evaluate a National Bureau of Standards (NBS) prototype calibration standard for linewidth measurements on IC photomasks and procedures for adjusting and calibrating optical-microscope systems in the 0.5- to 12-μm measurement range. Using procedures furnished by NBS, industrial participants measured line spacings and linewidths on NBS antireflective-chromium artifacts. A comparison of NBS linewidth values with participants' measurements showed that most differences were less than ±0.3 μm. A linewidth calibration significantly reduced systematic errors for most systems. Outliers in the data showed the need for measurement-control procedures. The standard deviation of the measurement process was ±0.1 μm or larger for about half of the systems. For some systems, there were significant day-to-day differences and operator differences.

The study showed that the NBS artifact and recommended procedures were adequate for calibrating an optical-microscope system which was in a state of statistical control. This study led to the issuance of NBS Standard Reference Material 474 (Optical Microscope Linewidth-Measurement Standard). [(301) 921-3786]

Nyyssonen, D., **Theory of Optical Edge Detection and Imaging of Thick Layers,** J. Optical Society America 72, pp. 1425-1436 (October 1982).

The optical microscope measurement of small objects, 0.5 to 10 μm, is complicated by the apparent change in the dimension of the object with a change in the spatial coherence of the illumination. Coherent edge detection methods

Dimensional Metrology, cont'd.

have been developed for the measurement of line objects on integrated-circuit photomasks and wafers. This paper presents a generalization of the coherent threshold equation which allows the extension to any state of partial coherence of the illumination as well as extension to the measurement of nonplanar objects. In the latter case, a waveguide model is developed for imaging of lines patterned in thick layers and is compared with experimental data. [(301) 921-3786]

Nyyssonen, D., **Design of an Optical Linewidth Standard Reference Material for Wafers,** Proc. Soc. Photo-Optical Instrumentation Engineers 342, Integrated Circuit Metrology, pp. 27-34 (October 1982).

Optical linewidth measurements on patterned wafers are complicated by the wide variety of materials and correspondingly wide variation in optical parameters, complex refractive index and thickness, used in the manufacture of integrated circuits. It has been shown that in addition to linewidth, two key parameters, the normalized local reflectance R and the optical phase difference ϕ at the line edge, determine the characteristics of the optical image and, therefore, affect the accuracy and precision of linewidth measurements. Both of these parameters, R and ϕ, are dependent upon the illuminating wavelength or spectral bandpass and the coherence parameter of the optical system. To achieve the measurement precision and accuracy required for VLSI dimensions (e.g., 10% tolerance for 1-μm linewidths), it is necessary to control coherence, spectral bandpass, and image integrity as well as to achieve reproducible edge detection and focus criteria. When a system can be operated without further operator intervention despite changes in the materials being measured, it is possible to calibrate the linewidth measurement system using a standard fabricated from only a few materials representing a range of image characteristics. The desirable characteristics of such a standard are discussed with respect to durability, edge definition, and equivalence of the image characteristics to materials used in the manufacture of ICs. A prototype design consisting of combinations of SiO_2 and chromium layers on a silicon substrate is presented. [(301) 921-3786]

Integrated Circuit Test Structures

Recently Published

Buehler, M. G., and Linholm, L. W., **The Role of Test Chips in Coordinating Logic and Circuit Design and Layout Aids for VLSI,** Proc. 2d California Technical Conf. on VLSI, Pasadena, CA, January 19-21, 1981, pp. 135-151.

This paper emphasizes the need for multipurpose test chips and comprehensive procedures for use in supplying accurate input data to both logic and circuit simulators and chip layout aids. It is shown that the location of test structures within test chips is critical in obtaining representative data, because geometrical distortions introduced during the photomasking process can lead to significant intrachip parameter variations. In order to transfer test chip designs quickly, accurately, and economically, a commonly accepted portable chip layout notation and commonly accepted parametric tester language are needed. In order to measure test chips more accurately and more rapidly, parametric testers with improved architecture need to be developed in conjunction with innovative test structures with on-chip signal conditioning. [Contact: Linholm, (301) 921-3541]

Proctor, S. J., and Linholm, L. W., **A Direct Measurement of Interfacial Contact Resistance,** IEEE Electron Devices Letters EDL-3, 294-296 (October 1982).

A method is described for directly measuring interfacial contact resistance

Integrated Circuit Test Struct., cont'd.

and estimating the degree of uniformity of the interfacial layer in metal-semiconductor contacts. A two-dimensional resistor network model is used to obtain a relationship between the specific contact resistance and the measured interfacial contact resistance for contacts with a homogeneous interfacial layer. Measurement results are given for 98.5 percent Al/1.5 percent Si and 100 percent Al contacts on n-type silicon. [Contact: Linholm, (301) 921-3541]

Yen, D., **Electrical Test Methods for Evaluating Lithographic Processes and Equipment**, Proc. Society Photo-Optical Instrumentation Engrs. 342, Integrated Circuit Metrology, pp. 73-81 (October 1982).

A test structure is a microelectronic device that is fabricated by the same process used to fabricate integrated circuits (ICs) and can be tested electrically to determine important process parameters. Test structures can be used to evaluate semiconductor materials, evaluate and control process uniformity, measure device and circuit parameters, obtain input parameters for circuit simulation programs, and determine the performance of processing equipment. This paper reviews previous work at NBS on the design, measurement, and application of two types of test structures that have been used for evaluating lithographic processes and lithographic equipment performance. First, the cross-bridge sheet-resistor test structure is described. Test results from electrical measurements on this structure can be used to determine the electrical linewidth of a conducting layer. The use of test chips containing arrays of identical cross bridges for determining the uniformity of a lithographic process will be described. Analysis of test results from these arrays has been used to identify and separate the contribution to linewidth nonuniformities introduced by individual equipment and processes. The precision to which linewidth can be determined using this structure will be discussed. Also, an electrical alignment test structure for determining the misalignment between two photomask steps will be described and an example of its use presented. Finally, an automated dc parametric test system used for measuring these structures will be described. [(301) 921-3621]

Yen, D., Linholm, L. W., and Buehler, M. G., **A Cross-Bridge Test Structure for Evalating the Linewidth Uniformity of an Integrated Circuit Lithography System**, J. Electrochemical Society 129, pp. 2313-2318 (October 1982).

This paper describes an electrical measurement method using a cross-bridge test structure to evaluate linewidth variations associated with integrated circuit lithography. Arrays of cross-bridge test structures are used to measure the uniformity of linewidth across a wafer. Utilizing this test structure array and high speed electrical test methods, sufficient quantities of data are obtained to make statistical comparisons and to evaluate a step-and-repeat system used to fabricate photomasks. The measured variation in linewidth, which was systematic and repetitive from sample to sample, was several tenths of a micrometer across a wafer and within a chip. This within-chip variation should be of special concern in the fabrication of devices that are sensitive to linewidth dimensions (i.e., MOSFETs with short channel lengths). The linewidth measurement precision using the cross-bridge test structure was shown to be 0.03 μm (1σ). [(301) 921-3621]

Process & Device Modeling

Released for Publication

Bennett, H.S., **Improved Device Physics for Calculating the Gain of Bipolar Structures in Silicon**, submitted to Proc. Workshop on Submicron Physics.

Process & Device Modeling, cont'd.

A model which is more physically correct than the extension of the empirical procedures of Slotboom and de Graaff for donor densities above 2.5×10^{19} cm^{-3} has been developed for the effective intrinsic carrier concentration n_{ie} in n-type silicon. This new approach, which is based upon quantum mechanics and optical measurements for the band-gap, has been applied to an npn transistor with a 1-μm emitter-base junction depth and with donor densities greater than 10^{20} cm^{-3}. Conventional device physics with even unrealistic carrier lifetimes does not predict the measured dc common emitter gain. The approach described here with carrier lifetimes comparable to those expected in processed silicon (~0.1 μs) does predict the gain correctly. [(301) 921-3541]

Lowney, J. R., and Bennett, H. S., **Effect of Ionized Donors on the Electron and Hole Densities of States in Silicon,** submitted to J. Applied Physics.

A self-consistent second Born approximation has been used to calculate the change in the electron and hole densities of states due to ionized donors in silicon. The results are compared with a previous partial-wave technique and found to be in good agreement for a case of common applicability, i.e., a donor density of 10^{20} cm^{-3} at room temperature. [(301) 921-3625]

Radiation Effects

Recently Published

Blackburn, D. L., Berning, D. W., Benedetto, J. M., and Galloway, K. F., **Ionizing Radiation Effects on Power MOSFETs During High Speed Switching,** IEEE Trans. Nucl. Sci. NS-29, 1555-1558 (December 1982).

Data on the effects of gamma radiation on the electrical characteristics of power VDMOS transistors are presented. The devices were exposed to radiation while the gate voltage was switching at 100 kHz or while held at a dc voltage. Several drain voltage configurations were also explored. The threshold voltage shifts observed begin to saturate at relatively low doses (~0.1 Mrad(Si)) for all but the worst case bias (V_G = +10 V). The threshold voltage shifts do not show significant dependence on drain voltage. The devices studied appear to be approximately an order of magnitude more efficient in trapping radiation generated holes than would be expected in a state-of-the-art radiation hardened planar MOSFET. [(301) 921-3541]

Wilson, C. L., and Blue, J. L., **Modeling of Ionizing Radiation Effects in Short-Channel MOSFETs,** IEEE Trans. Nuclear Science NS-29, 1676-1680 (December 1982).

The effect of ionizing radiation on short-channel MOSFETs is modeled using a charge-sheet approach. The primary effect of ionizing radiation is the introduction of oxide trapped charge (OTC) and interface trapped charge (ITC). Using a two-dimensional charge-sheet model, transistors with channel lengths between 4.65 μm and 0.27 μm were studied. A range of net OTC and ITC values of $\pm 4.0 \times 10^{11}$ cm^{-2} was used to study dose effects corresponding to 10^6 rad(SiO_2).

ITC and OTC cause significant effects in each region of operation. In the subthreshold region, the sensitivity of drain current to these charges is exponential. A more realistic model must include the energy distribution of the ITC charge as well as two-dimensional charge sharing effects. In the triode region, the effects of ITC and OTC are indistinguishable from two-dimensional charge sharing effects. This implies that a simple analysis of threshold voltage offsets in short-channel MOSFETs is incapable of providing a physically meaning separation of two-dimensional effects from radiation-induced effects.

Radiation Effects, cont'd.

In the saturation region, the combined OTC and ITC contribute a fixed charge component to the channel charge which can shift the critical field point at the edge of the pinch-off region in the channel. This critical field effect alters the formation of the "knee" region of the output characteristic and can alter the output conductance in the saturation region for short-channel transistors. [(301) 921-3541]

Packaging

Recently Published

Harman, G.G., and Harmison, K.A., **The Assessment of Hybrid Package Glass-Metal Seal Reliability Using Acoustic Emission Measurement Techniques,** International J. Hybrid Microelectronics, 5, pp. 248-259 (November 1982).

Experiments were conducted to assess potential reliability hazards to hybrid package glass-metal seals that may be encountered during hybrid assembly, or later in an avionics vibration environment, and to devise tests to reveal potential failures. The effects of an avionics vibration environment on the seals of PC-board-mounted hybrids were determined. In general, for flatpack type packages, lead fatigue failure occurs before seal damage to packages from high quality lots. Plug-in-type packages that were soldered into plated-through holes on PC boards appeared to be immune to vibration-induced seal damage and served as board stiffeners. An acoustic-emission (AE) monitored hot-stage shock test was developed that detects weak package seals either at the manufacturer's facility or on incoming inspection. The stresses that are applied to the internal extension of a package lead during bonding were monitored with AE, and "loose particles" of glass were found to crack off if the glass meniscus extended significantly under the lead. General conclusions of this study are that glass-metal seals in hybrid packages from high quality lots are very reliable even when subject to high thermal or mechanical stresses. However, the seals from packages "screened as good" from reject or poor quality lots are more subject to hermetic failure under the low to moderate stresses that may be encountered in handling or assembly. In addition, there is little correlation between visual inspection failures of glass seals and their hermeticity. [(301) 921-3621]

Harman, G. G., **Acoustic-Emission-Monitored Tests for TAB Inner Lead Bond Quality,** IEEE Trans. Components, Hybrids, and Manufacturing Technology CHMT-5, pp. 445-453 (December 1982).

This paper gives a brief introduction to acoustic-emission (AE) based tests applied to quality control in the electronics industry and describes some recent research on this testing technique. Equipment and circuits are described that may be used to implement such AE-monitored testing. Acoustic-emission-monitored test systems to determine the inner lead bond quality for Tape Automated Bonding (TAB) have been developed. These include a pull tester and a microfatigue tester for off-line evaluation of bond quality and metallurgical system reliability as well as an automatic on-line production bond quality tester. The microfatigue tester for TAB leads can apply a small oscillatory (up to 80 Hz) force on top of a constant force bias of a few grams. A major result of such fatigue tests was to show that the most common metallurgical system (tin-plated copper leads bonded to gold bumps) results in the formation of brittle intermetallic compounds which crack easily. The cracks propagate under cyclic stress and result in a very low fatigue life, compared to another TAB metallurgical system. The acoustic-emission-monitored inner lead bond integrity tester and lead-forming system is designed to be

Packaging, cont'd.

used on-line. Precision wedge-shaped tools rise up from below a clamped chip and apply a predetermined force (~100 mN) to the leads, which both nondestructively tests the bonds and forms the leads. If any lead separates, or partially separates from the bump, or the bump separates from the chip, the acoustic emission monitor can indicate failure and the device can be rejected. Data are presented to show various failure modes of the TAB system. [(301) 921-3621]

Ruthberg, S., **Leak Testing of Hermetically Sealed Electronic Components**, Proc. Qualtest I, American Society for Nondestructive Testing, Pittsburgh, PA., October 4-7, 1982, pp. 431-436.

In the electronics industry the requirements are for leak testing large numbers of relatively small sealed packages to very fine leak rates. A wide variety of package materials are used; internal volumes range from less than 10^{-3} cm^3 to greater than 10 cm^3; and the leak size reject level may be less than 1×10^{-9} $Pa \cdot m^3/s$. No single test can cover the leak size range. Present preferred methods such as the radioisotope, helium leak detector, and others are assessed as to range, precision, efficiency, and usefulness as based upon fluid transport mechanisms and experimental data. [(301) 921-3625]

Ruthberg, S., **Hermetic Testing of Large Hybrid Packages**, International J. Hybrid Microelectronics 5, pp. 215-232 (November 1982).

Hermetic testing is a routine operation in the microelectronics industry with millions of packages being screened each year. The technical literature contains numerous manuscripts on the subject. Test procedures are set forth in MIL-STD 883, in MIL-STD 750, in NASA Certification requirements, in ASTM standards, and in other documents. Yet disagreements in test results between supplier and user are common, different test methods provide different results for the same leak range on the same parts, results are dependent on package configuration, and the specified reject limits as set forth in the standards are somewhat arbitrary. Many of these problems can be understood by consideration of the gas transport mechanisms and of the different flow models selected for the various test methods. The greater internal free volume and the increased configuration complexity of the large hybrid package introduce additional constraints. The leak rate reject level for the larger package is considered from the viewpoint of moisture infusion rates, and their impact on test parameters is examined. Range, efficiency, and usefulness are examined for such popular test procedures as the helium leak detector, radioisotope, weight gain, and bubble methods as well as for others such as the tracer probe, differential pressure, and rapid cycle methods that are more appropriate for the larger package. The issues described above are discussed with the aid of graphical solutions and actual test data. [(301) 921-3625]

Ruthberg, S., **Semiconductor Measurement Technology: Graphical Solution for the Helium Leak Detector and Radioisotope Methods of Hermetic** Test: Master Graphs and Instructions, NBS Special Publication 400-73 (November 1982).

A graphical procedure for solution of the molecular flow approximation for the back pressurization method of hermetic test makes use of a set of characteristic curves and a test line. The characteristic curves are appropriate for both the helium leak detector and the radioisotope methods of test, although the form of the test line differs between the two methods. Master graphs of the characteristic curves and test lines are now provided in a scale and format appropriate for producing

Packaging, cont'd.

suitable worksheets with a copier. Step-by-step instructions are given for their use in obtaining solutions for various examples relative to the test specifications in acceptance standards such as MIL-STD 883B, etc. One set of characteristics is provided specifically for the helium leak detector mode as expressed directly in terms of air leak rate; a second set is provided specifically for the krypton-85 radioisotope mode also in terms of air leak rate; and a third set is retained in the original form for use with any tracer gas. [(301) 921-3625]

Other Semiconductor Topics

Recently Published

Scace, R.I., **The Semiconductor Equipment and Materials Institute Specification for Solar Cell Silicon,** Solar Cells 7, pp. 77-78 (1982).

The specification for solar cell silicon slices under development by the Semiconductor Equipment and Materials Institute is described. The specification covers physical and dimensional but not electrical attributes of the material. Work to establish standardized dimensions of slices is continuing. [(301) 921-3786]

Schafft, H.A., **Measurements for Commercial Photovoltaics: A Status Report,** Solar Cells 7, pp. 23-46 (1982).

The first part of this report discusses how reliable measurements play an important role along the chain of supplier-user links that make up the photovoltaics industry and its customers. Such measurements provide accurate information on materials, fabrication processes, product characterization and product needs on which sound decisions can be made to optimize the performance of processes and products. They are also indispensable for effective communication in the marketplace. The second part reviews the results of visits to industry to identify measurements-related issues that affect the expeditious development and application of photovoltaics. The results are organized into nine categories: (1) silicon characterization; (2) quality assurance; (3) electrical measurements of solar cells and modules (including accuracy and reproducibility of measurements, spectral response, reference cells and simulators and spectra distribution); (4) solar data; (5) interactions with customers; (6) measurement equipment; (7) module certification; (8) standards; (9) role of government. The third part of the report provides an overview of measurement and standards development activities. The intent of this is to promote an awareness of such work to encourage thereby greater participation and also timely use of the results of this work. [(301) 921-3621]

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SIGNALS AND SYSTEMS METROLOGY PROGRAM

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Released for Publication

Lawton, R.A., **Performance Standards for Waveform Recorders**, submitted to IEEE Trans. Nuclear Science.

A new technical committee for the Instrumentation and Measurement Society of the IEEE has been formed and is called Waveform Measurements and Analysis. The first task is to develop a performance standard for waveform recorders to satisfy a growing need for specifying the performance of the many new waveform recorders (transient digitizers, digital oscilloscopes, etc.) now coming on the market.

The work of the committee to date is described together with the efforts of the Electromagnetic Waveform Metrology Group at the National Bureau of Standards in Waveform Standards Development. [(303 497-3339]

Recently Published

Leedy, T.F., Gans, W.L., Bell, B.A., Lederer, P.S., and Nelson, R.E., **Automatic Test Equipment Calibration/ Performance Verification Evaluation and Research Program**, NBSIR 82-2601 (December 1982).

This work describes an experimental approach to verify the performance of selected third generation automatic test systems. The approach consisted of careful laboratory characterization of two types of signal sources. One was a dc and low frequency ac voltage source covering the range of approximately 100 mV to 200 V dc, and 300 mV to 140 V ac rms over a frequency range of 100 Hz to 10 MHz. The second source was a precision time synthesizer used to generate pulses of known durations from 50 to 1000 ns. Both of these sources were used to verify the ability of two automatic test systems to measure ac and dc voltages and time intervals. The methods used to characterize these sources and the measurement results of applying the sources to the two automatic test systems are discussed in detail. Recommendations for future efforts to improve the measurement capabilities and traceability of automatic test systems are also presented. [(301) 921-2727]

Schoenwetter, H.K., **Sensitive Analog Comparator**, IEEE Trans. Instrumentation & Measurement IM-31, pp. 266-269 (December 1982).

A strobed, sensitive analog comparator has been developed for use in the NBS Data Converter Test Facility. The comparator has a sensitivity of 1.5 μV and a response time of 30 μs to within 10 μV, following input steps up to 20 V. Signal voltages up to ±10 V are compared with reference voltage levels of opposite polarity, using a precision resistive divider. The input offset has a temperature coefficient of -1 μV/°C and changes less than ±5 μV under worst-case dynamic conditions. Following a strobe pulse, the digital output is retained until the next strobe pulse. Optical isolators provide isolation between the analog and digital circuits. [(301) 921-2727]

Cryoelectronic Metrology

Released for Publication

Hamilton, C. A., **100 GHz Binary Counter Using SQUID Flip Flops**, submitted to Proc. Applied Superconductivity Conference.

A binary counter using bistable dc SQUID's as flip flop circuits is reviewed. Its potential for frequency division in the THz range and for ultra high accuracy A/D conversion is discussed. [(303) 497-3740]

Cryolectronic Metrology, cont'd.

Hamilton, C. A., Lloyd, F. L., **8-Bit Superconducting A/D Converter,** submitted to Proc. Applied Superconductivity Conference.

The design, fabrication and testing of a superconducting 8-bit converter are presented. Experimental results show essentially monotonic output code at conversion rates of a few megahertz. An algorithm for automatic adjustment and potential problems of higher speed operation is discussed. [(303) 497-3740]

Kautz, R. L., **Chaos in Josephson Circuits,** submitted to Proc. Applied Superconductivity Conference.

Chaotic behavior in Josephson circuits is reviewed using the rf-driven junction as an example. Topics include the effect of chaos on the I-V characteristic, the period doubling route to chaos, and power spectra for the chaotic state. Liapunov exponents and the fractal geometry of strange attractors are also discussed. [(303) 497-3391]

Kautz, R. L., **Operation of a Superconducting Analog-to-digital Converter at Short Conversion Times,** submitted to Proc. Applied Superconductivity Conference.

The accuracy of a six-bit superconducting analog-to-digital converter has been tested at short aperture times. The accuracy was found to be good for conversion times down to 0.5 ns but significant errors were observed at a conversion time of 0.1 ns. These errors can be understood in terms of unwanted switching events that occur when the mode boundary separating two flux states is crossed rapidly.
[(303) 497-3391]

Muhlfelder, B., Johnson, W., Cromar, M. W., **Double Transformer Coupling to a Very Low Noise SQUID,** to be published in Proc. Applied Superconductivity Conference.

We have built and tested a planar dc SQUID with an integral matching transformer. The measured coupling is in good agreement with our calculations. We demonstrate that this configuration can efficiently couple a 1 μH signal source to a 16 pH SQUID loop. We have also built an uncoupled SQUID of this design that has an energy sensitivity, referred to the SQUID inductor, of 20 h over a flux range of about 0.15 ϕ_o.
[(303) 497-5375]

Sullivan, D.B., Radebaugh, R., Daney, D.E., Zimmerman, J.E., **An Approach to Optimization of Low-Power Stirling Cryocoolers,** sumitted to Conf. on Refrigerators for Cryogenic Sensors.

We describe a method for optimizing the design (shape of the displacer) of low-power Stirling cryocoolers relative to the power required to operate the systems. A variational calculation which includes static conduction losses, shuttle losses, and radiation losses, together with regenerator inefficiency, has been completed for coolers operating in the 300 K to 10 K range. While the calculations apply to machines with tapered displacers, comparison of the results with stepped-displacer cryocoolers indicates reasonable agreement. [Contact: Zimmerman, [(303) 497-3901 or -5427]

Van Zeghbroeck, B. J., **A Superconducting Current Injection Transistor,** submitted to Applied Physics Letters.

A new superconducting transistor has been investigated, both theoretically and experimentally. The device has a current gain of 10 and an estimated power-delay product of 90 attojoules. Possible applications include analog amplification and digital logic. It is shown that in principle, the gain of the device is limited only by its length.
[(303) 497-5121]

Zimmerman, J.E., Daney, D.E., Sullivan, D.B., **Development of a Second-Generation Low-Power Stirling**

Cryoelectronic Metrology, cont'd.

Cryocooler, submitted to Proc. Conf. on Refrigerators for Cryogenic Sensors.

A very low-power low-interference Stirling cryocooler is being developed based on principles and techniques developed over the last four years and described in several previous publications. It differs in several important details from those built previously. It uses a tapered displacer based upon an analytical optimization procedure. The displacer is driven by an auxiliary piston and cylinder (rather than by mechanical linkage) using some of the working fluid itself to provide the driving force. This provides smooth, vibration-free motion, and, more importantly, allows complete mechanical and spatial separation of the cryostat from the pressure-wave generator. Either of two different pressure-wave generators can be used. One uses a non-contaminating unlubricated ceramic piston and cylinder. The other uses a compressed-air-operated rubber diaphragm and motor-driven valves to cycle the pressure between appropriate limits.
[(303) 497-3901 or -5427]

Recently Published

Hamilton, C.A., **100 GHz Binary Counter Based on DC SQUIDS,** IEEE Electron Device Letters EDL-3, No. 11, pp. 335-338 (November 1982).

A binary counter using bistable dc SQUID's as flip flop circuits is demonstrated. All of the functions: LOAD, COUNT, STORE, READ, and CLEAR can be performed. The use of single flux quantum logic results in high sensitivity (10^{-18}J input pulse energy), high speed (100-GHZ count rate) and low power (10^{-7}W at 100-GHz count rate).
[(303) 497-3740 or 3988]

Antenna Metrology

Released for Publication

Hill, D. A., **Leaky Feeders and Subsurface Radio Communications,** submitted to IEEE Antennas and Propagation Society Newsletter.

This book review will appear in the IEEE Antennas and Propagation Society News letter. It is a summary of the contents and a technical evaluation of the 1982 book, Leaky Feeders and Subsurface Radio Communications, by P. Delogne.
[(303) 497-3472]

Recently Published

Baird, R.C., and Estin, A.J., **The Orbiting Standards Package: A Recalibratable Satellite Instrument Assembly for Measuring Large Earth Station Antennas,** Proc. Antenna Measurement Techniques Association, Las Cruces, NM, October 5-7, 1982, pp. 5.1-5.9.

The concept of an Orbiting Standards Package (OSP) has been discussed as a means of making direct measurements of fields, patterns, and polarization states of signals radiated from large earth station antennas. It would also have the capability of producing test fields of known intensities and arbitrary but well-defined polarization states, thereby enabling the determination of such parameters as G/T and Effective Receiving Area of earth stations. Recent developments in microwave six-port networks and in standard antennas would permit the all-electronic generation and detection of these signals. Moreover, it appears possible to recalibrate the satellite standards package to laboratory state-of-the-art accuracy following launch.
[(303) 497-3301]

FitzGerrell, R. G., **A Partial Loop Source of E and H Fields for Antenna Factor Calibration (A Loop Cell),** Proc. Antenna Measurement Techniques Association, Las Cruces, NM, October 5-7, 1982, pp. 15.1 - 15.22 [also to be published in IEEE Trans. Electromagnetic Compatibility].

Antenna Metrology, cont'd.

The loop cell is fabricated using two intersecting metal sheets joined at the intersection and forming a 36-degree angle. A section of a loop is mounted between two coaxial panel jacks, one on each sheet located at a distance equal to the loop radius from the intersection. A known current through this section of electrically small loop produces calculable E and H fields between the sheets in the plane of the loop. These known fields may be used to determine the antenna factor of small E and H antennas placed in the field if the mutual impedance due to the antenna images in the sheets is negligible and the antenna is not close to the open edges of the cell. Measured and calculated antenna factors agree within 2 dB between 0.25 and 1000 MHz. [Contact: H.E. Taggart, (303) 497-3462]

Repjar, A. G., Baird, R. C., and Newell, A. C., **Accurate Gain Measurements by an Extended Version of the NBS Extrapolation Method**, Proc. Antenna Measurement Techniques Association, Las Cruces, NM, October 5-7, 1982, pp. F7-F9.

A General Extrapolation Technique which eliminates the effects of ground reflections in absolute gain measurements has been developed. It extends the Extrapolation Method developed at NBS which, in its present form, utilizes only amplitude versus distance data and a curve fitting procedure to determine gain. The main advantages of the extrapolation method are its accuracy and generality, and there is essentially no upper frequency limit. It can, in principle, be applied to any type of antenna although some directivity is desirable to reduce multipath interference. Above 1 GHz uncertainties between 0.08 and 0.10 dB in gain are achieved routinely. Below 1 GHz however, a transfer standard is often broadbeam and produces ground reflections which cause oscillations in the amplitude data as a function of distance. These oscillations have longer periods than those due to the multile reflections between antennas which are routinely averaged out in the Extrapolation Method. For this reason, below 1 GHz and for gains less than about 10 dB, the antenna might not be calibratable by the usual Extrapolation Method, since errors in gain in the order of 1 to 2 dB could result. Now, however, by utilizing both amplitude and phase data as a function of distance, the extended version of the NBS extrapolation method can correct for ground reflections and can be used to calibrate antennas below 1 GHz. Uncertainties in gains, typical ly 0.12 dB, are achieved. The method and some results will be presented. [(303) 497-5703]

Noise Metrology

Released for Publication

Wait, D. F., Earth Terminal Measurement System Operations Manual (Revised), to be published as NBSIR 83-1679(R).

The Earth Terminal Measurement System (ETMS) was developed by the National Bureau of Standards to make accurate measurements of earth terminal and sat ellite parameters such as figure of merit (G/T), antenna gain relative to a reproducible reference level, the noise equivalent flux (NEF), and noise ulterior flux (NUF). This manual includes the theory of the measurements, measurement procedures, measurement trouble shooting, interpretation of the results, and a discussion of the ETMS software. [(303) 497-3610]

Laser Metrology

Recently Published

Sanders, A. A., Rasumussen, A. L., **A System for Measuring Energy and Peak Power of Low-Level 1.064 μm Laser Pulses.** NBS Tech Note TN-1058, (October 1982).

For the first time, transfer standards have been developed for measuring

Laser Metrology, cont'd.

1.064 μm laser pulses of duration about 10-100 ns, peak irradiance of about 10^{-8}-10^{-4} W/cm^2 and fluences of about 10^{-16}-10^{-11}J/cm^2. These energy and power measurement devices use PIN and APD silicon detectors, respectively, and can be used as stable transfer standards with total uncertainties (random errors computed at the 95 percent confidence level) of 10 to 15 percent. The system for calibrating these transfer standards is also described and consists of a cw Nd:YAG laser beam acoustooptically modulated to provide low-level laser pulses of known peak power and energy. A detailed evaluation of systematic and random errors is also shown.
[(303) 497-5341]

Optical Fiber Metrology

Released for Publication

Gallawa, R. L., Chamberlain, G. E., Day, G. W., Franzen, D. L., Young, M., **Measurement of Multimode Optical Fiber Attenuation,** to be published as NBS Tech Note TN 1060.

This document is one of a series which describes optical fiber measurement capabilities at the National Bureau of Standards. We concentrate here on the measurement of attenuation of multimode, telecommunication-grade fibers in the wavelength of 850 nm to 1300 nm. The document begins by discussing the need for restricted launch conditions, the most fundamental and crucial aspect of precise attenuation measurements. The limited phase space launch and the mode filter launch are discussed. Attention then turns to the practical matter of ensuring that the conditions of the restricted launch are met. The question of guaranteeing system linearity is included. A discussion of system noise is also included. The document describes measurement procedure and results obtained in the laboratory using three typical fibers. Results are presented for the two wavelengths of current interest: 850 nm and 1300 nm. The procedures are applicable to any wavelength, however. The document touches briefly on the matter of monomode fibers. Finally, a summary of the results from an interlaboratory comparison are presented to give perspective to the stability of a fiber subjected to handling and shipping. [(303) 497-3761]

Recently Published

Kim, E. M., Franzen, D. L., **An Interlaboratory Measurement Comparison of Core Diameter on Graded-Index Optical Fibers,** NBS Special Pub. SP-641, (October 1982).

Core diameter is an important geometrical parameter used in fiber specification. Unnecessary splice loss can be reduced by joining fibers of similar dimension. A core diameter of 50 μm has been internationally accepted for multimode graded-index fibers.
[(303) 497-3897 or -5342]

Other Fast Signal Topics

Released for Publication

Young, M., **Scratch Standards Should Not be Used to Predict Damage Threshold,** submitted to Proc. Laser Damage Conference.

The scratch and dig standards are the most widely used surface quality standards in the industry. In the proceedings of the 1980 symposium, Harold E. Bennett showed theoretically that damage ought to be initiated near a defect and related damage threshold to defect size.

Evidently because of one or both of these facts, some purchasers may use the scratch standards to specify the surface quality of components intended for high power laser systems. Although damage is often associated with the presence of a defect, this is an inappropriate use of these purely cosmetic standards. The classification of a particular scratch

Other Fast Signal Topics, cont'd.

correlates only very loosely with its width or depth. Even if a component is made of glass, little or nothing pertinent to damage threshold may be determined by classifying a scratch according to the existing cosmetic standards.
[(303) 497-3223 or -5342]

Young, M., **Questions Students Ask**, submitted to The Physics Teacher.

Answer to the question whether the greenhouse effect is a "hoax," submitted at the request of the associate editor of the journal. The greenhouse effect (radiation trapping) is not a hoax, although reduced convection plays a major role. [(303) 497-3223 or -5342]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Kotter, F. R., and Smith, A. N., **A Study of Air-Gap Breakdown at 28.5 Kilohertz**, submitted to IEEE Trans. Power Apparatus & Systems.

Measurements of the electrical breakdown of both quasi-uniform and highly non-uniform-field air gaps at a frequency of 28.5 kHz are reported. Gaps between a variety of electrode geometries ranged from a few centimeters to over two meters in length. Breakdown voltages significantly below the corresponding 60-Hz values were observed with electrodes for which appreciable pre-breakdown discharges occurred, and a pattern of "anomalous" flashovers at considerably lower than the normal breakdown voltages was noted with quasi-uniform field gaps. The results obtained appear to correlate well with the data found in the literature for higher frequencies but lower voltages. [(301) 921-3121]

McKnight, R. H., and Kotter, F. R., **A Facility to Produce Uniform Space Charge for Evaluating Ion Measuring Instruments**, submitted to IEEE Trans. Power Apparatus & Systems.

A low-speed wind tunnel containing space charge has been constructed and evaluated. The facility is used for testing the performance of ion counters and net space charge measuring devices. For different operating conditions, space charge densities in the test volume range from 2.5-5.7 x 10^{-8} C/m^3. The space charge density is spatially uniform within ±5% over more than 90% of the cross sectional area of the test volume, but decreases by approximately 20% between two positions separated by 1 m. Ion densities achieved in this system are comparable to those found near high-voltage dc transmission lines but are free from the accompanying large electric fields. [(301) 921-3121]

Recently Published

Fitzpatrick, G. J., Forster, E. O., Kelley, E. F., and Hebner, R. E., **Effects of Chemical Impurities on Prebreakdown Events in Toluene**, 1982 Annual Report, Conference on Electrical Insulation and Dielectric Phenomena, Amherst, Massachusetts, October 17-21, 1982, pp. 464-472.

Effects of chemical impurities on the breakdown process in toluene have been investigated under non-uniform field conditions using a high-speed image converter camera. The resistivity of the four samples investigated ranged from 10^9 to 10^{13} Ω·cm. It was noted that when the cathode was a point, streamer growth rate increased slightly with decreasing resistivity. When the needle was an anode, streamer growth rate was not measurably affected by changes in resistivity or applied voltage, requiring 1.6 ± 0.3 μs to cross the 3 mm gap. Independent of the polarity of the needle, the last step in the traverse leading to breakdown of the gap occurred at speeds greater than 1 x 10^6 cm/s. In purified toluene, more

Power Systems Metrology, cont'd.

than 200 kV could be applied to a 3 mm gap without breakdown. With the needle as a cathode, impurities facilitated the generation of secondary streamers which appeared to grow from the primary bush-like streamers. With decreasing resistivity, the branching of these streamers seemed to increase.
[(301) 921-3121]

Hebner, R. E., **Development of Power System Measurements -- Quarterly Report April 1, 1982 to June 30, 1982,** NBSIR 82-2586 (October 1982).

This report documents the progress on four technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period cables, the characteristics of positive and negative corona in compressed SF_6 gas, and the measurement of the space charge density in transformer oil subjected to 60-Hz excitation.
[(301) 921-3121]

Van Brunt, R.J., Misakian, M., Leep, D.A., Beaty, E.C., Gallagher, J.W., Cooke, C.M., Wyatt, K., and Gels, R.G., **1981 Annual Report: Technical Assistance for Future Insulation Systems Research,** NBSIR 82-2555 (November 1982).

A system for measuring the electrical properties of corona pulses has been characterized and is discussed. Additional data on the pulse height distributions of positive and negative corona pulses in pure SF_6 for point-plane electrode geometries are presented. Basic mechanisms for initiation of electric discharges in SF_6 for highly nonuniform fields have been investigated in a collaborative effort between NBS and the High Voltage Research Laboratory of the Massachusetts Institute of Technology. Effects of radiation, electrode geometry, and polarity on corona inception in SF_6 have been measured. Corona inception voltages and discharge initiation volumes have been calculated using the streamer criterion. Limitations of the streamer criterion as applied to SF_6 in highly nonuniform fields are discussed.

The statistics of electron avalanche growth in SF_6 have been measured and compared with results of theory. While the avalanche pulses, on average, followed expected theoretical behavior, the distribution was not found to be regular or to follow a simple stochastic theory. A thorough compilation and survey of electron swarm data for electro-negative gases used, and proposed for use, as components of gaseous dielectrics was completed. The parameters considered include: electron drift velocity, attachment coefficient, ionization coefficient, electron growth constant, diffusion coefficient, detachment coefficient, and characteristic energy. These are quantities needed for prediction of breakdown and modelling of gas discharges. Some of the important gases included in this study are: O_2, CO_2, SF_6, H_2O), air, nitrogen oxides, halogens, and various halogenated hydrocarbons, e.g., CF_4, C_2F_6, C_3F_8, C_4F_{10}, CCl_2F_2, $CClF_3$, c-C_4F_8, c-C_5F_8, Ch_3Br, CH_2Cl_3, $CHCl_3$, etc. In this report we include only an example of the data collected, namely that for SF_6. Using a gas-chromatograph/mass spectrometer, absolute concentrations of SOF_2 and SO_2F_2 and relative concentrations of H_2O in SF_6 have been measured as a function of total energy dissipated in corona discharges operated at power levels between 50 and 700 mW. The observed production rates for SOF_2 and SO_2F_2 appear to be proportional to power level, and the ratio of SO_2F_2 to SOF_2 concentrations for corona is considerably higher than that typically observed for arc discharges in SF_6.
[(301) 921-3121]

Superconductors

Released for Publication

Superconductors, cont'd.

Ekin, J.W., **J-B-T-ε Interaction in A15, B1, and C15 Crystal Structure Superconductors,** submitted to Proc. Applied Superconductivity Conference.

Experimental evidence is presented which indicates that the elastic strain effect on the critical current of high-field compound superconductors correlates strongly with the type of superconductor crystal structure. Large strain effects are observed in all practical A15 super conductors examined to date, including Nb3Sn, Nb-Hf/Cu-Sn-Ga, Nb3Al, and V3Ga. Strain is observed to have no measurable effect, however, on either the critical current or the critical field of superconductors having the B1 crystal structure [V_2(Hf,Zr)]. Strain limits placed on the mechanical design of superconducting devices are evaluated as a function of magnetic field for several A15 superconductors (Nb3Sn, Nb-Hf/Sn-Ga, and V_3Ga) and compared with the strain limits imposed by B1 and C15 superconductors. It is shown that the latter materials have mechanical design advantage in applications where the superconductor is subjected to strain (either compressive or tensile) in excess of 0.2%. [(303) 497-5448]

Fickett, F.R., **Oxygen-Free Copper at 4K,** submitted to Proc. Applied Superconductivity Conference.

Oxygen-free copper is the most common material used for stabilizing practical superconductors. This type of copper may show residual resistance ratios (RRR) that vary from 50 to 700 in the full soft condition. Knowledge of the exact RRR value is often essential for optimum system design. We have investigated the effect of stress, temper, and reanneal on the RRR and magneto-resistance of several hundred samples of oxygen-free copper from many sources. In this paper we describe the program and present a sampling of the results obtained to date. [(303) 921-3785]

Fickett, F. R., Goldfarb, R. B., **Magnetic Properties,** submitted to book, Materials at Low Temperatures, Chapter 6.

The magnetic properties of materials at low temperatures and techniques for their measurement are described. The low temperature literature is reviewed. The emphasis of the review is on metals and alloys of technological importance. Similarly, the treatment of theory and of measurement techniques is aimed toward the user interested in the more practical aspects of the subject. In every instance, however, references are given which allow the reader to pursue the subject at any level he may desire. [(303) 497-3785]

Gavaler, J.R., Greggi, J., Wilmer, R., Ekin, J.W., **Properties of NbN Films Crystallized from the Amorphous State,** submitted to IEEE Trans. Magnetics, MAG-19.

Cubic B1 structure NbN was prepared by annealing amorphous Nb-N films made by sputtering niobium in an argon-nitrogen atmosphere onto low temperature (350°C) substrates. Crystallized films on sapphire substrates have equiaxed grains while films on niobium are columnar. Grain sizes vary from 125 Å to >1000 Å. The highest superconducting critical properties measured in these films are: T_c = 16K, J_c (4.2, zero field) = 8 x 10^5 Amps/cm^2, and H_c2(1.3K) = 280 kG. Data on the effect of uniaxial tensile strain on J_c show that there is no measurable elastic (reversible) strain effect. Irreversible J_c degradation begins at an intrinsic tensile strain of 1.3% in the best case. [(303) 497-5448]

Goodrich, L.F., **The Effect of Field Orientation on Current Transfer in Multifilamentary Superconductors,** submitted to Proc. Applied Superconductivity Conference.

Experimental data and discussion are presented on the current distribution

Superconductors, cont'd.

when subject to multiple parallel and perpendicular magnetic fields along the length of a superconducting wire. The experimental data were taken on a rectangular pancake coil with the applied magnetic field in the plane of the coil. These data indicate that significant current transfer occurs in the first and last perpendicular magnetic field sections and little transfer occurs between these two sections. The implication for superconducting magnet design will also be discussed. [(303) 497-3143]

Hong, M., Hull, G.W., Holthuis, J.T., Hassenzahl, W.V., and Ekin, J.W., **Multifilamentary Nb-NB_3 Sn Composite by Liquid Infiltration Method: Superconducting, Metallurgical, and Mechanical Properties**, submitted to Proc. Applied Superconductivity Conference.

A rapid solid-liquid reaction mechanism has been used to form A15 Nb_3Sn in the liquid-infiltration processed Nb-Sn wire. Small, equiaxed A15 grains across the fine reacted filaments of 0.2-1.0 μ thickness were revealed with the transmission electron microscopy studies. A uniform Sn concentration near the stoichiometry was found in the A15 region. High inductive T_c's of 17.9 K with sharp transition widths (<0.3 K) and excellent overall J_c's of 10^4 A/cm^2 at 19 T and 4.2 K were achieved. Mechanical properties of the reacted wire are not worse than those of typical commercial bronze-process Nb_3Sn conductors, and ε(irrev) is slightly higher.
[Contact: Ekin (303) 497-5448]

Recently Published

Ekin, J.W., **Effect of Strain on the Critical Current and Critical Field of B1 Structure NbN Superconductors**, Applied Physics Letters 41(10) p. 996, November 1982.

The effect of uniaxial strain on the critical current of NbN superconductors has been measured at 4.2 K in magnetic fields from 6 to 22 T. Unlike A15 superconductors, the critical current of B1 structure NbN shows no measurable dependence on elastic strain, even at fields as high as 22 T. Furthermore, the bulk upper critical field determined from the high field critical current data is independent of uniaxial strain within experimental error (.5%). The irreversible strain limit ε(irrev) where the superconductor is permanently damaged was measured to be greater than 0.7% (0.5% intrinsic strain) in 0.2-)m thick-film samples. Values of ε(irrev) were observed to correlate with the microstructure of the NbN films as well as with the onset of substrate yielding. [(303) 497-5448]

Goldfarb, R.B., Fickett, F.R., Rao, K.V., Chen, H.S., **Spin-freezing Below the Ferromagnetic Transition Determined by the Imaginary Component of ac Magnetic Susceptibility**, J. Applied Physics, 53(11), p. 7687 (November 1982).

The temperature dependences of the real and imaginary components of ac magnetic susceptibility have been measured for a number of amorphous Fe-Mn and Fe-Ni alloys. The alloys have paramagnetic, ferromagnetic, and spin-glass intervals as a function of decreasing temperature. The spin-freezing temperature, Tfg is identified by examining the imaginary susceptibility χ". With decreasing temperature, χ", representative of losses, begins to increase at the Curie temperature Tc, and reaches a peak at a temperature identified as Tfg. No peak is seen at Tc. The real susceptibility χ' increases rapidly at Tc but decreases before reaching Tfg. For frequencies of 10 and 20 Hz, the peak magnitude of χ" is about half that of χ'. The results suggest that Tfg may be unambiguously defined by a peak in χ" in the case of spin glasses with intervening ferromagnetic states. [(303) 497-3650]

ELECTROMAGNETIC INTERFERENCE

Released for Publication

Crawford, M.L., **Improving the Repeat ability of EM Susceptibility Measure ments of Electronic Components When Using TEM Cells,** submitted to SAE Technical Paper Series 830607, International Congress and Exposition, Detroit, MI, February 28 - March 4, 1983

This paper outlines a systematic approach, using a TEM cell, for evaluating the electromagnetic (EM) radiated susceptibility of electronic equipment. The purpose of the paper is to provide guidelines, for those using TEM cells for performing EM susceptibility measurements, to improve the repeatability and, hence, the value of their test results. The paper describes the test setup, details the step-by-step procedures to use in performing susceptibility measurements, and discusses pertinent information related to the range of application and limitations associated with the use of TEM cells.
[(303) 497-5497]

Kanda, M., Ries, F.X., Driver, L.D., and Orr, R.D., **Electric and Magnetic Field Sensor Concept for Simultaneous Near-Field Electromagnetic Field Measurements,** submitted to Proc. 1983 EMC Symposium and Exhibition, Zurich, Switzerland, March 8-10, 1983.

This paper describes a single sensor to perform simultaneous near-field electric and magnetic field measurements. The theory indicates that it is possible to obtain the loop-mode and dipole-mode currents using a loop terminated with identical loads at diametrically opposite points. The theory also indicates that it is possible to adjust the loop-mode and dipole-mode by adjusting the load impedance, and thus obtaining an ideal load impedance for achieving equal electric and magnetic responses of the loop. Preliminary experiments have been performed to verify these results.
[(303) 497-5320]

Koepke, G.H., and Ma, M.T., **A New Method for Determining the Emission Characteristics of an Unknown Interference Source,** submitted to Proc. 1983 EMC Symposium and Exhibition, Zurich, Switzerland, March 8-10, 1983.

Quantitative determination of the radiation characteristics of an unknown interference source is of importance to the users, manufacturers, and regulatory authorities. The theoretical background and measurement procedures for a new method to achieve this objective are presented with experimental results. [Contact: Ma, (303) 497-3800]

Recently Published

Chew, H., **Electromagnetic Modeling of Oil Shale Retorts for Remote Sensing Purposes,** IEEE Trans. Geoscience and Remote Sensing, GE-20, No. 4, pp. 510-517 (October 1982).

We report here some work on the modeling of oil shale retorts for electromagnetic sensing techniques. The aim is to obtain useful information about the contents of the retort (e.g., rubble size, void ratio, etc.) by means of electromagnetic probes. In this work, the retort is modeled by a spheriod with an average dielectric constant which depends on the void ratio. The near field due to a radiating dipole source in the vicinity of a spheroidal retort is computed using the Extended Boundary Condition Method due to Waterman, Barber, and Yeh. Numerical results are given at 4 MHz for a retort with major axis 45.7 (150 ft.), minor axis 25.1 m (82.5 ft.), bulk dielectric constant 8.8 + 3.7j, and various void ratios. The results indicate feasibility of determining the void ratio by remote electromagnetic measurements. It is also believed that this work may be of interest beyond the immediate context of oil shale retort modeling. Contact: R. Jesch,
[(303) 497-3496]

Electromagnetic Interference, cont'd.

Ma, M.T., and Koepke, G.H., **A Method to Quantify Radiation Characteristics of an Unknown Interference Source,** NBS Tech. Note 1059 (October 1982).

A new method for determining the radiation characteristics of leakage from electronic equipment for interference studies is described in this report. Basically, an unintentional leakage source is considered to be electrically small, and may be characterized by three equivalent orthogonal electric and magnetic dipole moments. When an unknown source object is placed at the center of a transverse electromagnetic (TEM) cell, its radiated energy couples into the fundamental transmission mode and propagates toward the two output ports of the TEM cell. With a hybrid junction inserted into a loop connecting the cell output ports, one is able to measure the sum and difference powers and the relative phase between the sum and difference outputs. Systematic measurements of these powers and phases at six different source object positions, based on a well-developed theory, are sufficient to determine the amplitudes and phases of the unknown component dipole moments, from which the detailed free-space radiation pattern of the unknown source and the total radiated power can be determined. Results of simulated theoretical examples and an experiment using a spherical dipole radiator are given to illustrate the theory and measurement procedure. [(303) 497-3800]

Taggart, H.E., **Radiated EMI Instrumentation Errors,** EMC Technology, Magazine, Vol. 1, No. 4, pp. 26-35.

The purpose of this article is to address the various types of instrumentation errors that can be encountered when performing EMI measurements. The various types of errors associated with the instrumentation will be discussed and suggestions made as to how they can be reduced. Since the instrumentation consists of basically an antenna connected to a receiver, the errors associated with the antenna, the receiver, and connecting cables will be addressed. Calibration errors associated with the various parts of an EMI measuring system are discussed. These include (1) antenna calibration errors (loops, monopoles, and dipoles), (2) receiver calibration errors (rf voltmeter, attenuator, and linearity), (3) mismatch errors (antenna and receiver) and (4) antenna ground effect errors. A table summarizing these errors is included in the conclusions. [303) 497-3462]

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CEEE CALENDAR

1983

September 12-13 (Gaithersburg, MD)

The IEEE CHMT Society and NBS are jointly sponsoring the **VLSI Chip Packaging Workshop.** New developments and critical overviews in the following areas will be presented: hermetic, plastic package design and evaluation; package thermal design, characteristics, problems, and test methods; bonding and interconnections for high lead count devices; coordinated chip, interconnection and package design, including design for automatic assembly; materials for VLSI packaging; die attach methods and problems for large chips; and new package-related failure mechanisms. [Contact: G.G. Harman (301) 921-3621]

November 14-16 (Boulder, CO)

15th Annual Symposium on Optical Materials for High Power Lasers (Laser Damage Symposium). This Symposium, now in its 15th year, has become the major forum for information exchange on problems of high power laser materials. The Symposium is an outgrowth of the activities of the ASTM Subcommittee on Laser Standards. The subject matter of this year's symposium is about equally

CEEE CALENDAR, cont'd.

divided between problems of high power laser materials, especially thin film coatings, of importance in laser fusion, and problems of CW lasers, especially in the infrared, relevant to DoD applications. There will also be discussion of the problems of uv and visible lasers, of long term interest in both agencies. NBS has co-sponsored this meeting since its inception.
[Contacts: Susie Rivera (303) 497-5342 or Kit Kline (303) 497-3678]

December 8 (Gaithersburg, MD)

The IEEE Electron Devices Society and NBS are co-sponsoring the **Power Semiconductor Devices Workshop**, which is designed to bring together those actively working in the field of power semiconductor devices. The Workshop will be held in conjunction with the IEEE International Electron Devices Meeting in Washington, D.C.
[Contact: F. Oettinger, (301) 921-3541]

1984

February 6-10 (San Jose, CA)

The Symposium on **Semiconductor** Processing will be sponsored by ASTM and co-sponsored by NBS, SEMI, and Stanford University. Technical sessions will address new problems arising from rapid increases in device complexity and performance and the emergence of integrated systems-on-a-chip, automated factories, and silicon foundries.
[Contact: R.I. Scace, (301) 921-3786]

June 18-21 (Gaithersburg, MD)

Co-sponsored by IEEE and NBS, the **Power Electronics Specialist Conference**, will bring together specialists in circuits, systems, electron devices, magnetics, control theory, instrumentation, and power engineering for discussions of new ideas, research, development, applications, and the latest advances in power electronics.
[Contact: F. Oettinger (301) 921-3541]

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All technical information included in this document has been approved for publication previously.

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

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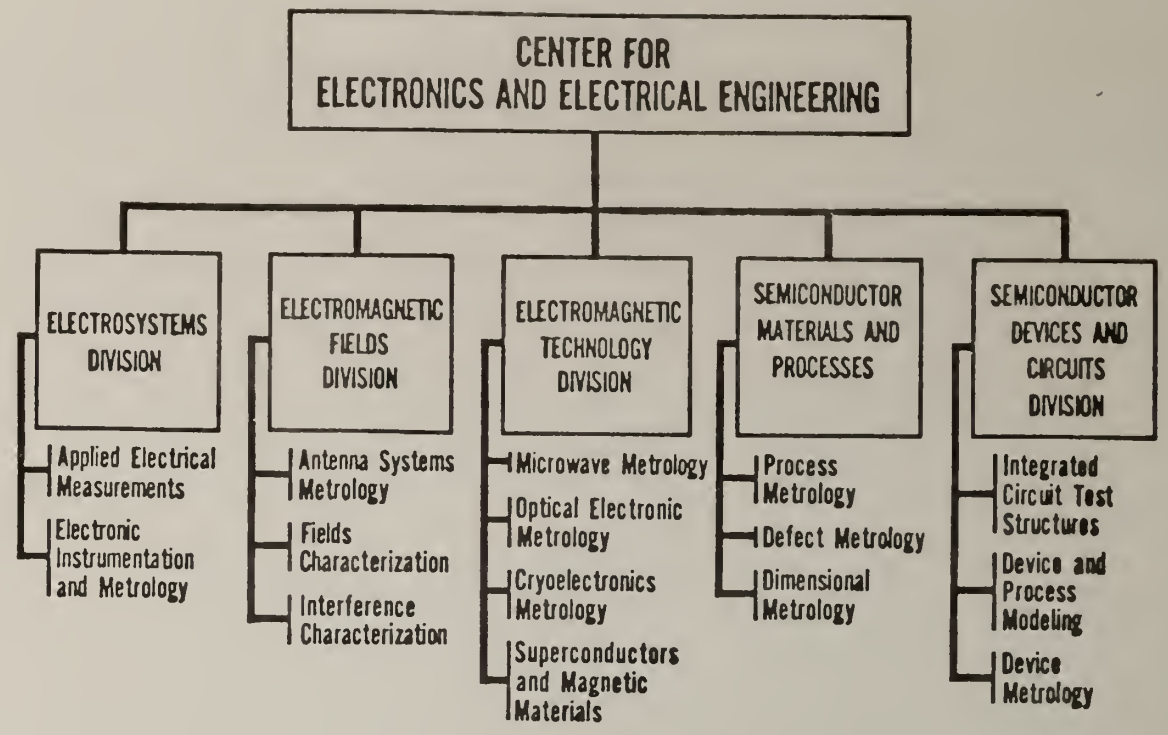

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